# Hint, instruction, and practice: The necessary components for promoting spontaneous diagram use in students' written work?

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# Hint, Instruction, and Practice: The Necessary Components for Promoting Spontaneous Diagram Use in Students' Written Work?

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**Abstract.** This study investigated the efficacy of providing a hint, instruction, and practice in promoting spontaneous diagram use in the written work of 21 students undertaking an undergraduate course in education. The course required the students to regularly produce for homework a one-page explanation of what they had learned. In the first few weeks of the course, they rarely included diagrams in their explanations. Following a hint to use diagrams (provided as comment/feedback on their homework), diagram use significantly increased. When instruction in effective use of diagrams was provided, the level of diagram use maintained but did not increase. However, when practice in using diagrams was additionally provided, further significant increases in diagram use followed, which maintained over the ensuing weeks of the course. These findings suggest that to spontaneously use diagrams in their written work, students need to be provided a combination of advice, instruction, and practice in such use.

**Keywords:** spontaneous diagram production, written communication, strategy use advice and encouragement, diagram use instruction, skills practice

## 1 Introduction

The research literature concerning the use of diagrams in communicative situations indicates that such use is efficacious [1–4]. When both verbal representations (such as text on a printed page or words spoken by a teacher) and visual representations (such as illustrations or other forms of diagrams shown on a page, board, or screen) are appropriately used in conveying a message, both the verbal and visual channels of the message recipient's working memory are engaged, making it more likely that the intended message would be understood. In simple terms, the message recipient not only reads or hears the content of the message, but also sees what it might 'look like.' When integrated, the meaning of what has been read/heard *and seen* could make understanding of the intended message easier. For example, it would likely be easier to grasp the structure of a topic if it is not only written or spoken about but also shown in terms of a schematic diagram.

Despite the apparent usefulness of including diagrams in communicating information to others, there is one serious problem: students generally lack spontaneity in using diagrams in such communication [5–7]. There is not a great deal of research that has been conducted regarding this problem, but what research has revealed about the factors that influence student diagram use in communication – particularly written communication – is outlined in the following subsection.

### 1.1 Factors that Influence Diagram Use in Communicative Situations

One important finding is that the intended audience of the communication makes a difference as to whether diagrams would likely be used [5, 7]. More specifically, students are more likely to include diagrams when writing notes for their own selves, and less likely to include diagrams when writing explanations for other people. Manalo and Uesaka [7] suggested that a possible reason for this is that diagrams may be perceived as serving more useful functions in writing notes for oneself (e.g., summarization of main points, connection of key ideas). In contrast, diagram use may be viewed as more risky when producing explanations for others: such use could lead to misunderstanding as diagrams tend to leave out non-essential details, and they demand a greater degree of interpretation on the part of the audience. It is also possible that students view diagrams as less 'formal' than words when explaining what they know in academic contexts. Such a view could arise because important means for conveying knowledge – such as essays, reports, and test answers – explicitly require writing in words. However, diagrams are at most optional for such products, and may be considered as belonging more to the planning stage rather than the final product.

Another important finding is that some individual- and task-related factors influence the likelihood of diagram inclusion in written communication [6, 7]. The reason is that these factors affect the cognitive processing cost associated with diagram production. One example of an individual factor is language proficiency: when students have to use a foreign language to explain information they have learned, they are less likely to employ diagrams – especially if their proficiency in that language is low. This may seem counter-intuitive in that one would imagine that students would more likely resort to the use of diagrammatic representations if they have to use a language they are not so proficient in (i.e., to compensate for what they might find difficult to explain in that language). However, there is limited processing capacity in working memory [8, 9] and when students have to use a language they lack proficiency in, production of text in that language depletes the cognitive processing resources in working memory to the extent that insufficient resources remain for the production of any diagrams. Manalo and Uesaka [6] reported evidence for this: Japanese university students' proficiency in English was found to significantly correlate with their use of diagrams when explaining what they had learned in English, but not in Japanese.

Where task-related factors are concerned, an example is the imageability of the information that needs to be explained (i.e., how easy or difficult it is to imagine). Manalo and Uesaka [6, 7] reported findings that when students have to explain information of low imageability, they are less likely to use diagrams. The reason is essentially the same as for the previously mentioned language proficiency finding: con-

structing diagrams to represent information that is hard to imagine demands more cognitive processing resources in working memory, and is therefore less likely to be undertaken because there may be inadequate resources for it.

In the area of math word problem solving, an instructional intervention that has been found to improve students' spontaneous diagram use is the provision of teacher verbal encouragement to use diagrams and practice in drawing diagrams [10]. Uesaka, Manalo, and Ichikawa reported that students who had been provided both encouragement and practice in drawing (in addition to regular instruction in problem solving) subsequently showed the highest improvement in spontaneous diagram use [10]. They explained this finding in terms of verbal encouragement helping students to appreciate the value of diagram use in problem solving, and practice in drawing developing students' procedural knowledge in constructing appropriate diagrams. This explanation is congruent with previous arguments that student learning strategy use depends on their knowing that those strategies would be useful, as well as their knowing how and when to use those strategies [11, 12]. However, previous research had not examined whether encouragement to use diagrams and practice in using diagrams would similarly be effective in increasing spontaneous diagram use in communicative situations.

One intervention that has been shown in previous research to be effective in promoting students' spontaneous diagram use in communicative situations is peer interaction. Uesaka and Manalo reported that when students were required to verbally explain information they had learned to peers in interactive learning situations, they spontaneously drew more diagrams in the process of explaining (more so than students in a control condition where they had to similarly explain, but in a non-interactive manner) [13]. Uesaka and Manalo explained that interaction facilitates awareness of the usefulness of diagrams in such communicative situations: through feedback and questions that the explainer's interlocutor provides during the interaction process, the explainer comes to realize the limitations of using words alone, and the need to use other representations – particularly diagrams – to successfully convey the content of the explanation. The finding of this study confirms the importance of perceiving the value of diagram use if students are to spontaneously use diagrams in their communicative efforts.

However, even though peer interaction has been found to be effective in promoting spontaneous diagram use in communication *while students were in the process of interacting,* no evidence has been found that such diagram use transfers to other subsequent communication tasks. In fact, Manalo, Uesaka, and Sheppard [14] reported that despite a spontaneous increase in student diagram use during an interactive peer explanation phase in their study, diagram use reverted to previously low levels in a subsequent (non-interactive) explanation writing task. The reason for this transfer failure is important to understand as self-regulation in learning requires that students are able to apply their knowledge at crucial times during learning performances [15].

There are two possible reasons for the lack of spontaneous diagram use in the subsequent explanation writing task. One is that, from the peer interactive explanation session, the students could have acquired a more task-specific knowledge that "diagrams are useful *when verbally explaining in an interactive manner to others,*" rather than the more abstract, general, and transferrable knowledge that "diagrams are useful

*when explaining information to others.*" The other possible reason is that, even if they had acquired the more abstract knowledge about the usefulness of diagrams in explaining, many of the students might have lacked the necessary skills in constructing the appropriate diagrams for the explanations they were writing.

### 1.2 Problem Statement and Overview of the Present Study

The main challenge addressed in the present study was how to promote students' spontaneous use of diagrams in written communication – particularly when explaining information to others. A secondary challenge was to design an intervention that would have ecological validity – in other words, an intervention that would work not only in an experimental situation, but also in real educational contexts.

The interventions used in the present study aimed at directly addressing issues that have been identified in previous research as likely impediments to spontaneous diagram use. Thus, to address the possibility that students might not realize the value of incorporating diagrams in their written work, a hint about the usefulness of diagrams was provided by the instructor in the form of individual written feedback on explanations that students produced. To address the possibility that students might be deficient in knowledge about diagram use for enhancing the communicative effectiveness of written work, instruction on such use was provided. And to address the possibility that students might lack skills in constructing the appropriate diagrams to use when explaining various kinds of information, practice was provided in such construction.

The second challenge concerning ecological validity was addressed by conducting the study described here within a real undergraduate course in education studies in a national university in Japan. The course is taught entirely in English, and the majority of students who take the course are Japanese, for whom English is a foreign language. During the semester when this study was conducted, some international students were also enrolled in the course, but all students had English as a second or foreign language. Apart from covering various theories, concepts, and research in education, the goals of the course include the development of students' communicative competence. Thus, course conduct incorporates activities requiring oral and written output from students (e.g., discussions, written exercises) to facilitate the development of such competence. One such activity is for students to complete a one-page written explanation homework task each week, in which they are asked to explain what they have learned in the course during that particular week to an imaginary student who does not know anything about the contents of the course. The interventions in this study focused on students' spontaneous use of diagrams in that homework assignment.

The main hypothesis tested in this study was that the provision of a hint to enhance perception about the usefulness of diagrams, instruction to improve knowledge about effective use of diagrams, and practice to develop skills in constructing diagrams would result in significant increases in students' spontaneous use of diagrams in explanations they write. A related second hypothesis was that, while enhancing students' perception about the usefulness of diagrams and improving their knowledge about effective use of diagrams would result in some students using diagrams more spontaneously, it would not be until the students receive practice in the construction

of appropriate diagrams that the majority would evidence the desired spontaneity in diagram use. This hypothesis was based on previous findings suggesting that perception of usefulness (indicated by increased diagram use during interactive explanations with peers [13, 14]), and knowledge about effective use of diagrams (indicated by diagram use in notes that students had taken for their own selves [14]) may not be enough to promote spontaneity in diagram use *when constructing written explanations for others*. Practice may additionally be necessary as students may lack skills in constructing diagrams that they could be sufficiently confident about in terms of enhancing the effectiveness of explanations they write for other people.

A third hypothesis tested in this study was that, from beginning to end of semester, students would evidence improvements in their spontaneous diagram use in both note taking and explanation writing as measured by their performance in tasks (pre- and post-intervention tests) that are different from the one they receive the intervention in (i.e., their weekly explanation writing task). A related fourth hypothesis was that, while in the pre-intervention test students might evidence higher diagram use in note taking compared to explanation writing, such a difference would no longer be present in their post-intervention test (i.e., diagram use in explanation writing would increase to the extent that it would no longer be lower than in note taking). Previous research has shown that students tend to use more diagrams when taking notes for their own selves compared to when writing explanations for others [5, 7], so it would be interesting to examine whether the interventions used in this study might be sufficient to reduce or eliminate that difference in use.

## 2 Method

### 2.1 Participants

The participants were 21 undergraduate students taking an introductory course in education studies (aged approximately 19–20 years; females = 11; Japanese = 13, other nationalities = 8). Faculty ethics committee approval was obtained for the conduct of this study. The students were provided written and verbal explanations at the beginning of the course that some of the work they produce would be analyzed for research and course development purposes. They were given an option of having their work excluded from such analyses, but all students provided written consent for use of their work.

### 2.2 Materials and Procedure

**Pre- and Post-Intervention Tests.** The course that the students were taking comprised a total of 14 weekly 90-minute class sessions. At the end of the first and the thirteenth class sessions, the students were given a reading/note taking and explanation-writing task as ‘independent’ pre- and post-intervention tests (i.e., ‘independent’ in the sense that these had nothing to do with the regular content of the course). These were administered to obtain measurements of the students’ use of diagrams in note taking and explanation writing, with the use of materials that could be experimentally

controlled (in contrast to the regular materials used in the course, over which experimental control was deemed inappropriate). Two short English passages, both just under 600 words in length, were used as reading materials: one about the jigsaw classroom, and the other about theory of mind. These topics were selected because they were similar to the kinds of topics dealt with in the course, but were not included as part of the course. Care was taken in preparing these reading materials to make them as equivalent as possible. Approximately half of the students were randomly given one passage, while the other half received the other passage, in the pre-intervention test. The students then received the other passage they had not read in the post-intervention test.

The procedure used in administering the pre- and post-intervention tests were the same. The students were given 10 minutes to read and take notes from the passage they were assigned. They received an A4-size sheet of paper on which to take notes, and they were informed that they could use their notes in an explanation task that would follow, but that they would not be able to refer back to the passage they were reading. The students were then given 10 minutes to produce an explanation of the passage they had read, imagining that their audience was another student who knew nothing about that topic. After this, they were given five questions to answer. The first two required responses on 5-point Likert-type scales, and asked about prior knowledge concerning, and ease/difficulty in understanding, the passage they had read. The other three questions were to assess their comprehension of the passage and required short, written answers.

**Weekly Explanation Homework and Interventions Used.** As mentioned in the introduction section, the course required students to complete and submit an explanation homework task each week (except in weeks 1, 6, and 14). This homework required students to explain the most important points they had learned from the class session that week. They were asked to imagine that their reader was another student who knew nothing about the topics covered in the course. They were also informed that the explanation should be sufficient on its own (i.e., the reader should understand it without having to be provided additional verbal explanation). The students received an A4-size sheet of paper to write their explanation on. The homework was collected the following week for instructor feedback, and returned the week after that.

It should be noted that no marks or grades were given for each homework task sheet that the students completed, only written comments about the quality and adequacy of the explanation they produced. However, the students were required to include those sheets in their portfolio (for submission at semester end), which was allocated 40% of the total course grade. In the grading rubrics for that portfolio, marks were allocated for satisfactory completion and quality features of the homework tasks. However, no mention was made in those rubrics of diagrams, or of expectations for students to include diagrams. Thus, diagram use in the explanation homework tasks was neither an explicit requirement, nor a feature directly linked to marks or grades.

The interventions used in the present study were (1) a hint about the usefulness of diagrams in writing explanations, (2) instruction in the effective use of diagrams for such explanations, and (3) practice in the construction of diagrams to use in explain-

ing various kinds of information. These interventions were provided at key stages during the weeks of the semester to find out their effect on student diagram use.

The hint was provided as a comment that "including diagrams could make your explanations easier to understand" (the same wording was used for all students). This was written, together with any other comments, on the bottom of students' homework task sheets. (The sheets with feedback were returned to students individually during class, and students were encouraged and given a brief amount of time during class to read over the feedback they had received.) Provision of the hint was staggered so that some of the students (randomly selected) received it earlier than others. For those who received the hint earlier, it was provided on their week 3 homework, which was submitted in week 4 and returned in week 5; thus, any effects that the hint could have had would have been evident from their week 5 homework. For the students who received the hint later, the corresponding weeks were: hint given on week 5 homework, submitted in week 7 (as the students worked on a project in week 6), and returned in week 8; thus, any effects would have been evident from their week 8 homework.

All students received the instruction on effective use of diagrams in week 10; thus any effect of that instruction should have been evident from their week 10 homework. Approximately 20 minutes instruction was provided toward the end of the class session, covering reasons for using diagrams (i.e., to help clarify own understanding of the information to be explained, and because research has shown that people learn better from words and pictures than from words alone [e.g., 3]), and ways to use diagrams in explanations (i.e., to illustrate, provide an overview or structure, show process or cause-and-effect relationships, and compare or contrast). Each of these reasons and ways was explained and examples of the kinds of diagrams referred to were shown. However, the students were not given an opportunity during the week 10 class session to practice constructing diagrams.

Practice in constructing diagrams was provided during the week 11 class session. Approximately 30 minutes toward the end of the class was allocated to this. First, the instructor quickly reviewed the key points from the instruction about diagram use provided in week 10. Then students were given a photocopy of the week 3 explanation homework they had earlier submitted. This particular homework was selected because not a single student included a diagram for it. The students were provided a new sheet with instructions to consider and draw diagrams they might be able to include to make their explanation easier to understand. The topic covered in the week 3 class session was early childhood education, and a few examples of diagrams students produced during the practice session in week 11 are shown in Figure 1. During the session, the instructor was available to provide comment and/or feedback, and students could briefly discuss their newly constructed diagrams with other students.

In addition to their usual explanation homework, the students were also assigned an additional homework task in week 11, which was to construct one diagram for each of the ways diagrams could be used in explanations using any of the topics/materials that had been covered in the course up to that time. This homework was assigned to give the students additional practice in constructing diagrams, and would have likely required at least 30 minutes of their time to complete. Examples of the diagrams that one student produced for this homework are shown in Figure 2.

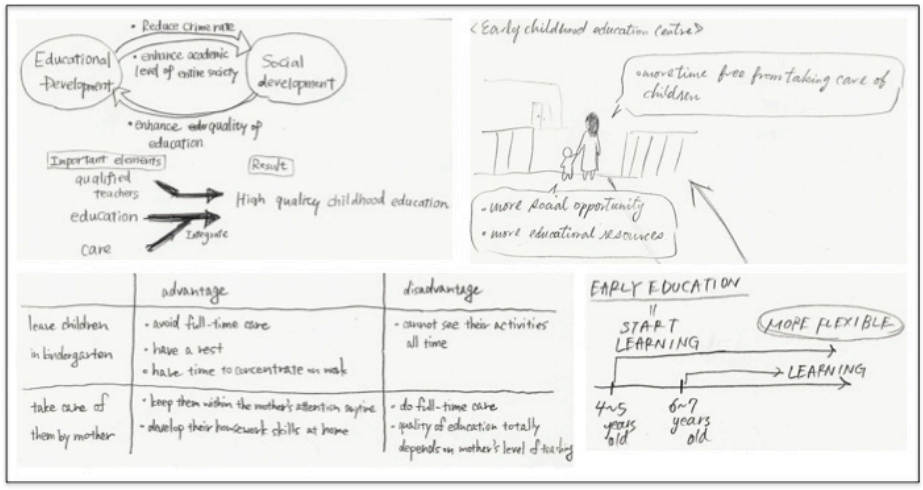


**Fig. 1.** Examples of diagrams that students produced during the week 11 class practice

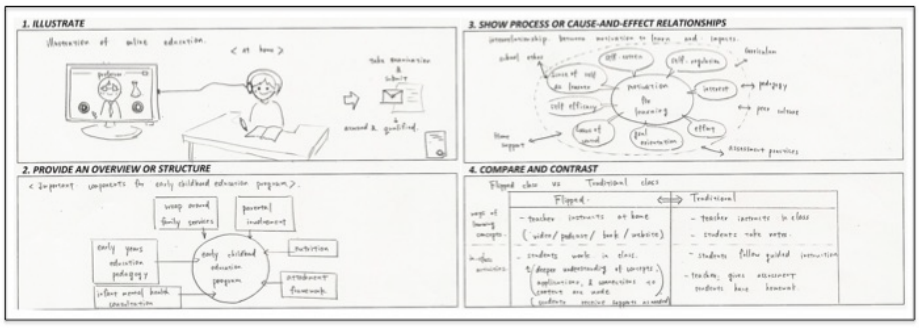


**Fig. 2.** Examples of diagrams that one student produced for week 11 practice homework

No intervention was provided in weeks 12 and 13, so the explanation homework that students submitted during those weeks' classes were examined for maintenance of any spontaneous diagram use they might have acquired as a consequence of the interventions provided in the preceding weeks.

For the sake of clarity, Table 1 shows the intervention phases and the homework tasks that were categorized under those phases.

**Table 1.** Weekly Homework Task Numbers Belonging to the Different Phases of the Study, According to Whether the Hint was Provided Early or Later

| Hint Provision | Baseline | After Hint | After Instruction | After Instruc-tion + Practice | Maintenance |
|---|---|---|---|---|---|
| Early | 2, 3, 4 | 5, 7, 8, 9 | 10 | 11 | 12, 13 |
| Later | 2, 3, 4, 5, 7 | 8, 9 | 10 | 11 | 12, 13 |

### 2.3 Analysis

The students' homework sheets were examined to determine whether the students used a diagram in their explanations. Use of at least one diagram was scored as 1, and no diagram as 0 (the number of diagrams used was not taken into consideration in scoring). For the purposes of this study, a diagram was defined as any representations produced by the students, other than representations in the form of words, sentences, or numbers on their own. For example, drawings and charts counted as diagrams, as did arrows and similar symbols when these were used to link three or more concepts. Analysis focused on whether the interventions made a difference to the proportions of students using diagrams in their homework over the course of the semester.

For the notes and explanations that the students produced in the pre- and post-intervention tests, similar scoring (i.e., to determine whether or not a diagram was used) was applied. The proportions of students using diagrams in their notes and explanations at pre-intervention and at post-intervention were then compared.

The first author and a research assistant with no vested interest in the outcomes of this study independently carried out data scoring. The kappa coefficient values for inter-rater agreement were .92 for the homework data and .85 for the pre- and post-intervention tests data, both of which represent almost perfect agreement [16].

## 3 Results

### 3.1 Did the Interventions Have an Effect on Students' Diagram Use in Their Homework?

An analysis of variance (ANOVA) was carried out on the students' diagram use data in their homework tasks, with timing of hint provided (early, later) and intervention phase (baseline, after hint, after instruction, after instruction + practice, maintenance) as independent variables (between-participant and within-participant, respectively). The authors had earlier agreed on a criterion of "no more than three missing assignments" for any student's data to be included in the analysis and, based on this decision, one student's data was excluded from this analysis.

The results revealed a significant effect due to phase, $F(4, 72) = 12.07$, $p < .001$. Figure 3 shows the mean proportions of student diagram use in each of those phases. The effects due to the timing of hint and the interaction were both not significant.

Simple main effects analysis using Ryan's method (with the significance level set at .05) revealed significant differences in pairwise comparisons between all the phases, except (i) between "after hint" and "after instruction", and (ii) between "after instruction + practice" and "maintenance". These results indicate that provision of the hint significantly increased students' diagram use in their homework. However, the provision of instruction did not add any further significant increases to the level of diagram use already achieved following the hint provision. It was not until practice was additionally provided that further significant increases in diagram use ensued. This level of diagram use was maintained over the remaining two weeks of the semester. These findings lend support to the first two hypotheses posed in this study.

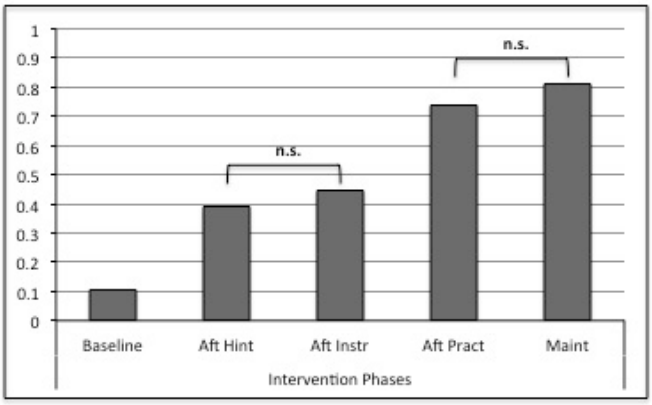


**Fig. 3.** Mean proportions of student diagram use during the intervention phases

### 3.2 Did the Students' Diagram Use in Their Written Work Increase From Beginning to End of the Semester?

An ANOVA was carried also out on the students' diagram use data in the pre- and post-intervention tests. Passage order (jigsaw classroom or theory of mind passage given at pre-intervention), time (pre-intervention, post-intervention), and tasks (note taking, explanation writing) were the independent variables, with passage order being a between-participant variable, and the other two being within-participant variables. Two students' data were excluded from this analysis as they were absent for the post-intervention test.

The results revealed a significant time effect ($F(1, 17) = 4.18$, $p < .001$), and a marginally significant interaction effect between time and task ($F(1, 17) = 3.99$, $p = .062$). The effect due to passage order was not significant.

The significant effect due to time indicates that the students used more diagrams at post-intervention compared to pre-intervention. Simple main effects analysis of the interaction between time and task revealed that, at pre-intervention, the students' diagram use in note taking was significantly higher than in the explanations they produced, $F(1, 34) = 5.14$, $p = .030$. However, the difference between note taking and explanation writing was no longer significant at post-intervention, $F(1, 34) = .233$, $p = .633$. These differences can clearly been seen in Figure 4. The simple main effects analysis also revealed that diagram use in note taking significantly increased from pre- to post-intervention ($F(1, 34) = 7.533$, $p = .010$), as did diagram use in explanation writing ($F(1, 34) = 30.671$, $p < .001$). These findings lend support to the third and fourth hypotheses posed in this study.

The students' responses to the questions asked in the pre- and post-intervention tests indicated that the students had limited prior knowledge about the topics of the passages, but they understood most of their content. Overall performance in the comprehension questions was high (range of means for the questions = 70–100% correct) confirming that the students mostly understood the content of those passages.

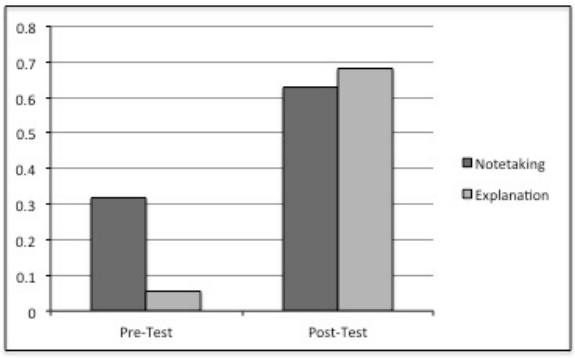


**Fig. 4.** Mean proportions of student diagram use in note taking and explanation writing in the pre- and post-intervention tests

## 4 Discussion

The hypotheses tested in this study were supported by the results. The interventions were effective in increasing diagram use in the students' explanation writing, as evidenced by the significant effect of intervention phase, which confirmed the first hypothesis. As Figure 3 shows, the majority of students did not include diagrams in the explanations they produced until after both instruction *and practice* had been provided, confirming the second hypothesis about the importance of practice in promoting spontaneity in diagram use. The third hypothesis was also confirmed: significant improvements in diagram use were observed not just in the students' homework but also in their post-intervention test performance. Finally, in the students' post-intervention test performance, diagram use in note taking and in explanation writing was found to be equivalent (which was not the case in their pre-intervention test performance), suggesting a change in students' perceptions about the relative value of including diagrams in notes and in explanations – and confirming the fourth hypothesis.

### 4.1 Why the Interventions Worked

As noted in the introduction section, the interventions used in this research aimed at directly addressing issues that had previously been identified as likely impediments to diagram use. Those issues were failure to realize the value of incorporating diagrams in written work, deficiency in knowledge about the use of diagrams for enhancing the communicative effectiveness of written work, and inadequacy of skills for constructing diagrams that may be deemed useful [7, 13, 14]. Thus, the success of the interventions used in this study can be explained in terms of reducing or eliminating barriers that students may encounter in diagram use.

The hint provision might in effect have provided students with two of the three sorts of knowledge about strategies that Paris, Lipson, and Wixson [11] considered as necessary for invoking learning strategies: knowing *that,* and knowing *when.* The instructor-provided hint could have made students realize *that* diagrams could be

useful *when* attempting to write explanations for other people. Although such knowledge may sound obvious to diagrams researchers, it may not be as obvious to the majority of students as academic socialization mainly emphasizes the use of verbal/textual representations in conveying to others knowledge that has been acquired – such as in tests, and in reports and other forms of assignment [5].

The effect of timing of the hint provided was not found to be significant in the statistical analysis undertaken. The analysis compared the overall diagram use of the students who received the hint early and those who received it later. Thus, it would make sense that their overall diagram use would be equivalent, otherwise the groups could be considered as dissimilar or even non-comparable. However, as shown in Figure 5, the hint provision produced the predicted increases in diagram use among the early-hint and later-hint groups in weeks 5–7 and weeks 8–9, respectively.

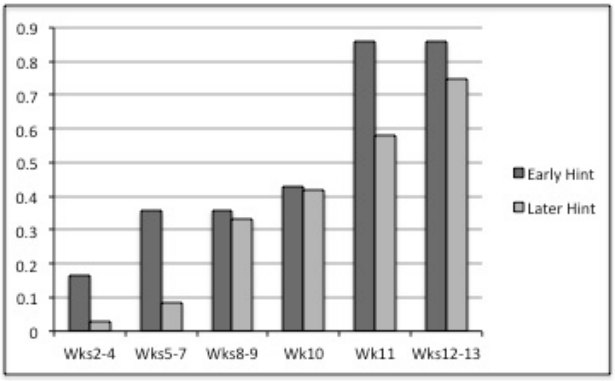


**Fig. 5.** Mean proportions of diagram use by the "early hint" and "later hint" students over the weeks of the semester

The provision of instruction as part of the interventions provided was intended to address one of the key reasons for failure to use learning strategies that Garner [12] identified: knowledge deficiencies. Students may be aware of certain learning strategies or even that those strategies are supposed to be effective, but if they are deficient in their knowledge about how those strategies can be used, those students are unlikely to use the strategies. Hence, students may know about diagrams and their usefulness in learning situations but, for those students to actually use diagrams, they first need to know how they can use diagrams in target learning situations.

An interesting and somewhat unexpected finding in the present study was that the provision of instruction did not result in any further increase in student diagram use beyond what had already been attained following the hint provision (see Figure 3). The most likely explanation for this is that instruction may have provided students with useful semantic knowledge about diagram use in explanations, but not the procedural knowledge necessary for them to confidently apply that semantic knowledge to their own work. This explanation is supported by the finding that, when practice in constructing diagrams was later provided, a significant increase in the proportion of students who used diagrams followed. However, to avoid any possible misunder-

standing, it should be stressed here that *practice on its own* – without instruction – would also likely be insufficient. Without the corresponding instruction, students would lack essential semantic knowledge, and any practice they undertake would lack focus on the variety of ways for effectively using diagrams.

The third component of the intervention – practice – was crucial in that it provided students with opportunities to apply instruction they had received and/or knowledge they already possessed about useful ways to incorporate diagrams in explanations. The third sort of knowledge that Paris et al. [11] considered necessary for students to use learning strategies was knowing *how*. The findings of this study suggest that knowing how has two vital components: knowledge about how the strategy can be used, and skills about how that knowledge can be utilized in target situations. Without the latter, students may not spontaneously use a strategy: they may hesitate or desist in using the strategy as it could be too troublesome to use [cf. 17], and they could end up making mistakes in using it. Practice, however, promotes the development of procedural knowledge (i.e., knowing what to do). Thus, acquiring the necessary procedural knowledge would likely result in making the prospect of using the strategy appear less troublesome and less fraught with potential pitfalls.

Prior research has revealed that cognitive processing cost could also influence students' spontaneity in using diagrams in communicative situations [6, 7]. The instruction and practice components of the interventions used in the present study probably contributed to reducing the processing cost involved in diagram production. Semantic knowledge about how to use diagrams acquired through the instruction component, and procedural knowledge about how to construct diagrams developed through the practice component, likely made it less cognitively costly to think about and construct the diagrams that could assist in clarifying the explanations the students were writing.

### 4.2 Transfer to Other Tasks

A very important finding in the present study was that increases in students' spontaneous diagram use were observed, not just in their weekly homework tasks (where the interventions were implemented), but also in the post-intervention test administered toward the end of the semester. This suggests transfer of spontaneity in diagram use from the homework situation to the test situation. Although the tasks involved in these were similar (e.g., explanation was required in both homework and the explanation writing component of the test), there were also important dissimilarities: the post-intervention test was conducted under time constraint, and it also included note taking (in which increased diagram use was also observed).

The significant increase in spontaneous diagram use in note taking and explanation writing in the post-intervention test is also important because those tests were independent and experimentally controlled. With the real materials that the students were learning in class, it was difficult and ethically problematic to impose such control. It was therefore possible that factors like imageability (which can affect diagram use [6, 7]) varied between the materials covered in the class sessions each week. Thus, to be able to verify the increase in students' spontaneous diagram use using that independent and experimentally controlled measure was crucial from a research perspective.

Furthermore, although this has not been reported in the results section of this paper as it was found through a subsequent post hoc analysis, transfer was also observed in the students' final test writing: 13 out of the 21 students (62%) still used diagrams in some of the test question answers they produced. That final test differed in format from the students' weekly homework, and it was held several weeks after the last intervention had been provided. This finding is therefore indicative not only of transfer to a somewhat different written explanation task, but also of maintenance of the intervention effect over a longer period of time.

A crucial question to address in future research is whether the diagrams that students spontaneously produce truly enhance the communicative quality of their written work. This question was deemed outside the scope of the current paper because of time and publication-length constraints. However, one indication that diagram use did enhance the quality of students' written work is that, in the final test mentioned above, the students who used diagrams scored significantly higher (mean = 18.69, $SD$ = 1.25) than the students who did not (mean = 15.88, $SD$ = 2.75), $t(19) = 3.23$, $p$ = .004. The test questions were scored solely on correctness and quality of the answers produced, and no points were allotted to inclusion of diagrams. The higher score of those who used diagrams therefore suggests better quality answers, possibly as a consequence – at least in part – of incorporating the diagrams. Again, this was found through a later post hoc analysis and therefore not included in the main results.

### 4.3 Conclusion

The most important finding in the present study is that it is possible to promote spontaneity in students' diagram use in written communication – not in an experimental setting, but in a real educational context. The components of the interventions used (hint, instruction, and practice) appeared to have brought about the desired, significant change in the students: from almost none of them using diagrams in their written work at the beginning of the semester, to almost all of them employing diagrams in their production of such work at the end of the semester.

Diagram use is efficacious in many educational and daily life contexts and, as such, it is generally considered important for students to acquire the skills necessary for such use. Few research studies however have addressed the question of how to promote spontaneity in students' diagram construction and use – even though in reality there would be few daily life situations where people would find diagrams supplied to them for their use. The present study developed and tested one viable method for promoting student spontaneity in diagram use in the area of communication. The authors hope that the successful outcomes reported here would stimulate further research into this important but largely neglected aspect of diagram use.

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